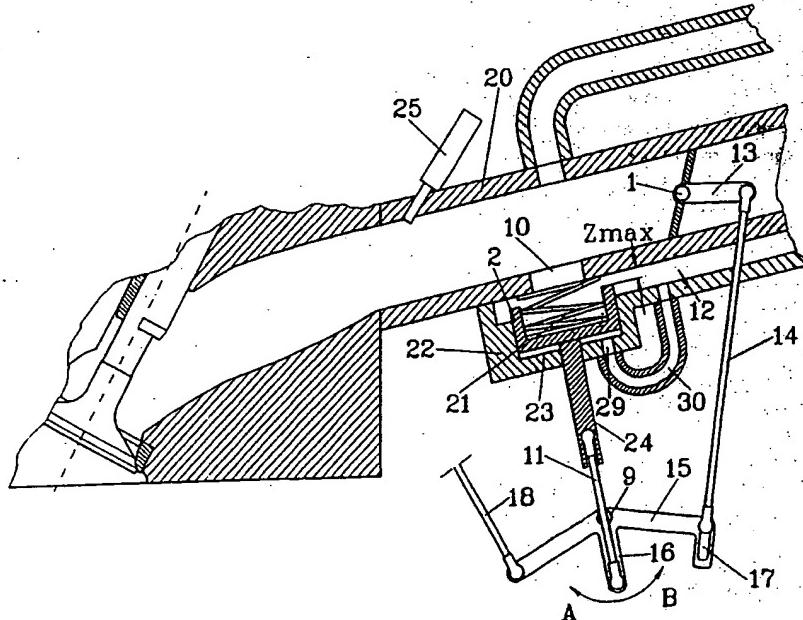




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: DEVICE TO REDUCE GAS EXCHANGE LOSSES OF AN INTERNAL COMBUSTION ENGINE



## (57) Abstract

Device for reducing gas exchange losses or pumping losses of an internal combustion engine comprising a throttle (1) for controlling the pressure in the inlet manifold for the combustion air with or without fuel to the cylinders of the motor. In the inlet manifold (20) to every cylinder is provided a separate (1) throttle whereby the low pressure side of the inlet manifold relatively said throttle is supplied air or fuel-air mixture of higher pressure than the pressure of the low pressure side by a valve which at the start of every inlet stroke is kept open and which closes before the inlet valve of the engine closes whereby the closing function of the valve is actuated by the position of said throttle.

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DEVICE TO REDUCE GAS EXCHANGE LOSSES OF AN INTERNAL COMBUSTION ENGINE

Technical field

5

The present invention refers to a device for reducing gas exchange losses or pumping losses of an internal combustion engine comprising a throttle for controlling the pressure in the inlet manifold for the combustion air with or without fuel to the cylinders of the engine.

10

Background of the invention

15

Much has been done to reduce the fuel consumption of internal combustion engines. This generally can be achieved by making the combustion, that is the release of energy as efficient as possible. The design of the combustion chamber and the composition of gas is of great importance. Also, by reducing the internal losses in the form of flow and friction losses of the engine the efficiency can be substantially raised.

20

Flow losses in the form of gas exchange or pumping losses arise when combustion gases are going to be replaced by the engine by a new working medium after the working stroke. These losses are particularly obvious when the engine is controlled by a throttle and is operating in the low load and partial load range. The car engines of today are very much oversized to offer relaxed and restful driving with a large power in reserve for rapid acceleration. This implies that driving in the city and on the main, with other words the most common driving conditions, the engines are operating with large pumping losses.

25

30

At inlet of fresh gases to the cylinder of an internal combustion engine there is pressure drop because of the flow in the ducts and at the valves and the throttle. These

pressure drops gives rise to a negative pressure in the inlet system. In the same way at exhaust of exhaust gases there is a positive pressure in the exhaust system because of the flow resistance. This pressure difference is the reason for work to be consumed to pump the gases into and out of the cylinders and this is called gas exchange work or pumping losses.

In the pV-diagram, see Fig. 1, the area between the inlet line and the exhaust line the pumping work. In the logarithmic pV-diagram, Fig. 1a, the pumping cycle is brought about and therefore this is used hereinafter. To compare, the real proportions are seen in the linear diagram, Fig. 1b.

The power of the Otto engine is controlled by varying the inlet gas mass. Since the inlet volume all the time is constant, and equal to the cylinder volume of the engine, the density of the gas has to be varied. This is achieved by the gas being choked by a butterfly valve or a throttle. The control method per se thus implies that the pressure of the inlet gas has to be reduced in order to reduce the power. At full load the throttle is fully open and in that case very small pressure losses are obtained at the inlet. At low load however there is a very small throttle opening which gives a very great pressure loss because of the choking. Through the throttle control the engine thus has to work with a lower pressure than atmospheric pressure on the inlet side. When the piston is taking in air at a lower pressure a larger amount of work is consumed. The lower load on the engine the lower is the inlet pressure which makes the pumping losses increase. From fig. 2 can be seen that the pumping losses increase considerably at low load. A comparison at constant speed shows that the pumping losses at full load may be about 5 % of indicated power while they are about 50 % at low load.

The engines of passenger cars of today are driven during the

major part of the time at very low load, at the magnitude of 20% of the maximum power. At normal driving thus a very little throttle opening is used, which results in the pumping losses being largest in the operational range in which 5 passenger cars are most often driven.

The method according to which the pumping losses are going to be reduced according to the present invention can be derivated from the equation of state:

10

$$pV = mRT \quad \text{implies} \quad p = mRT/V \quad \dots(1)$$

Here we let  $p$  be the inlet pressure in an arbitrary position of the inlet stroke. The rest of the parameters are:

15

$m$  = mass (air-fuel mixture)

$R$  = gas constant

$T$  = temperature of the mixture

$V = sA + V_c = \text{volume}$

20

$s$  = stroke

$A$  = piston area

$V_c$  = compression volume

All efforts to reduce the pumping losses at low load aim to 25 increase  $p$ . Without affecting the maximum power of the motor from eq. (1) it can be achieved by:

\* A decrease of  $V$

\* An increase of  $m$

30 \* An increase of  $T$

At low load the volume can be reduced by in some way reducing the stroke: either the geometric or the effective intake stroke. With the effective intake stroke is here 35 meant the part of the stroke when intake occurs. Moreover the volume can be reduced by disengaging a number of cylinders of multiple cylinders at low load.

Methods in known technique which apply reducing of the effective intake stroke are available in two variants namely:

5 Early closing of the intake valve, EIVC (Early Intake Valve Closing), and late closing of the intake valve, LIVC (Late Valve Intake Closing). Devices according to these methods controls the engine power by continuously varying the closing time and lift of the intake valve.

10 With EIVC is meant that intake valve closes before lower dead point. In certain designs there is no throttle at all. A degree value after the designation of the control method states the time for valve closing in reference to the lower dead point.

15 E.g. EIVC 60: The valve closes 60 degrees before the lower dead point.

20 At load control using EIVC the intake valve opens as in a conventional engine just before the intake stroke. As the cylinder volume increases during the intake stroke the fuel-air mixture is let in at nearly atmospherical pressure, since no choking butterfly valve is present.

25 Thereafter the power is controlled by closing the valve when a sufficient amount of mass has flowed in. With other words the power is controlled by the time for valve closing. After the closing the gas expands simultaneously as the piston completes the intake stroke. Thereafter compression, expansion and exhaust follows as in a conventional engine.

#### State of the art

30 The technical solutions by which EIVC and LIVC are achieved are relatively complicated.

35 In Fig. 3 is shown a mechanical system according to Porsche with two cam shafts which can be displaced in phase with respect to each other and gives EIVC. One cam shaft operates as a conventional cam shaft and handles the lift. The other decides for how long time the valve should be open.

In Fig. 4 is shown a system according to Volkswagen, where the conventional valve system is maintained. A rotating slide valve instead has been placed in front of the usual inlet valve. By coupling the rotating slide valve to the cam shaft and make it phase displaceable with respect to said shaft an early valve closing is accomplished, EIVC.

5 In Fig. 5 is shown an alternative method to control the valves, by which the valve system is provided with controllable hydraulic valve lifters and in such a way that both 10 EIVC and LIVC are accomplished.

15 In the US patent specification 4 158 352 is described a method and apparatus for introducing additional air into the intake manifold to aid in the starting of an internal combustion engine. A flapper valve is provided on the throttle valve which is operative according to the pressure differential across the flapper valve blade. Said throttle blade is preformed to be in an open position when the engine is 20 cranked prior to starting. When the engine starts, the manifold pressure will rapidly drop and the large pressure differential across the flapper will close the hole and normal idle vapor flow will occur.

25 The device according to this patent is not intended to give EIVC - function and neither can give such a function, particularly in the case it was mounted on a single cylinder engine since the sensitivity of the flapper valve for the mass flow is not actuateable in the same way as in the 30 device according to the invention, in which is used a stop lug which is movable by a mechanical coupling to the throttle control and gives different stroke of the valve (corresponds to the flapper opening  $x$  in the US patent specification). At increased throttle opening the EIVC-function is 35 gradually shut off since the stop lug forces the valve to closing.

The object of the invention

5       The object with the present invention is to accomplish the EIVC function by means of an uncomplicated device at the inlet part of the engine whereby the drawbacks in above related technique are substantially eliminated.

10      The problem related above which forms the basis of the invention is solved by means of a device according to the accompanying patent claims.

Description of the drawings

15      With reference to the accompanying drawing in the following preferred embodiments of the present invention will be described.

## In the drawing

Fig. 1 shows a pV - diagram of an Otto engine in which the present invention is used;

20      Fig. 2 shows a diagram of specific fuel consumption g/kwh as a function of share of output power in percent, F = friction losses, P= pumping losses;

Fig. 3-5 shows the state of art related to devices to achieve EIVC;

25      Fig. 6 shows a lateral view of an inlet manifold in which a first embodiment of the invention is contained;

Fig. 7 shows an X-ray view of a system of throttles comprising the first embodiment of the invention;

30      Fig. 8 shows a central sectional of a manifold in which a second embodiment of the invention is contained;

Fig. 9 shows a diagram of the operation of a valve according to the invention from which can be seen mass flow of the gas as a function of differential pressure over the valve;

35      Fig. 10 shows a pressure- volume diagram in which is incorporated partly a normal throttle (solid line) and partly a valve according to the invention (dashed line).

Description of embodiments

With reference till Fig. 6 is shown a section of an inlet manifold 200 comprising a throttle 1 on which has been provided a leaf formed valve flap 210 which is resiliently mounted by means of the cut-in resilient portion 31 with a mounting point in the throttle disc 100 by means of the rivets 121. In the throttle disc there is an opening 230, the rim of which forms a valve seat 220 for the valve flap 210. The throttle is operated by means of a first arm 40 to which is coupled a link 140. In the resting position the valve flap 210 is separated from the valve seat 220 on the throttle disc 100 by means of a prebending in the portion 31.

The presetting of the valve flap 210 with reference to the valve seat 220 is carried out by means of setting heel 60 which is provided on a tube shaft which is concentric with the shaft supporting the throttle disc 100. The throttle is operated by means of a lever 102 which is coupled to a distributor arm 51 by the way of a driver 190 and provided with bearings at the inlet manifold at the central axis 101. The arm actuates partly the lever 40 of the throttle and partly the lever of the valve 130 by way of links 140 and 112, 110 respectively. In the distributing arm 51 one of the branches is provided a sector formed slot in which runs the driver 190. The sector formed slot is designed with such an angle opening, that the valve 210, 220 opens completely before the throttle opens.

The function of the valve 210, 220 according to the present invention is the following:

In Fig. 6 the throttle is shown closed and the valve 210, 220 is completely open. At the beginning of the inlet stroke the valve is kept open by the valve spring 31 and allows a certain volume gas mixture to flow into the cylinder. Because of the flow a certain pressure difference arises over the valve flap and when this pressure difference overcomes

the spring force the valve 210, 220 closes. This closing occurs before the intake valve of the engine closes and thereby gives EIVC - function.

5. With reference to Fig. 9 mass flow as a function of difference pressure at different settings of the heel 60 is illustrated, the displacement of which gives different distances  $z$  between the valve flap 210 and the valve seat 220. In the figure the closing function at four different settings  $z_1$  -  $z_4$  in linear steps of  $\delta z$   
10 that is  $z_2 = z_1 - \delta z$ ;  $z_3 = z_1 - 2\delta z$ ;  $z_4 = z_1 - 3\delta z$ .  
In Fig. 6 as well as in Fig. 8 the maximum distance or the stroke  
 $z = z_{max}$  for respective valves is shown.
- 15 Extreme positions for the throttle of the system in Fig. 6 thus are:  
A = fully open throttle which gives a completely closed valve 210, 220 ( $z=0$ ) and B= completely closed throttle and completely closed valve 210, 220 ( $z=0$ ).  
20 The positions A and B does not give EIVC.

With reference to Fig. 8 in a second embodiment of the valve according to the invention shown a central section of the inlet manifold 20 of an injection engine comprising the injection nozzle 25 and a throttle 1. On the low pressure side a partial load air duct 12 enters which supplies the cylinder of the engine a preheated gas mixture e.g. air from the atmosphere by an air filter, at higher pressure than that of the low pressure side by a circular opening 10. A cylindrical house 22 is provided against the opening 10 in which house a piston 2 slides, which piston is open at one end and receives a valve spring 21 which forces the piston 2 against the bottom part 23 of the house 22. At the closed end of the piston is fixed an operating rod 24 at the free end of which is provided a groove which admits movement of the piston 2 towards the tube 20 whereby the angle position of the link 11 determines the stroke of the piston 2. The link 11 by way

In a third embodiment of the invention, the second embodiment is completed with an exhaust turbine driven compressor which feeds the partial load air duct 12, whereby through this embodiment a more favourable pressure and temperature process is obtained during the inlet and compression phase.

of the lever system 16, 15 is mechanically connected to the throttle wire 18.

Extreme positions for the throttle of the system in Fig. 5 8 are:

A= completely open throttle which gives closed valve 2, 20 (z=0) and

B= closed throttle and completely closed valve 2, 20 (z=0).

The positions A and B does not give EIVC.

10 Through the bottom portion 23 there is a hole against which is connected a bypass duct 30 from the partial load air duct 12. The throttle is connected to the throttle wire by way of the lever 13, the link 14 and the lever 15.

15 In the branch of the lever 15 which is connected to the lever 13 is provided a slot 17 which lets the throttle be closed until the valve 2, 20 has been opened completely with a movement of the throttle control from the extreme position B. Fig. 8 shows a completely open valve ( $z_{\max}$ ) and closed 20 throttle 1.

In the same way as in the first embodiment above we consider a separate inlet stroke. At the beginning of the inlet stroke the valve 2, 20 is kept open by the valve spring 21 25 and allows a certain volume to flow into the cylinder by the partial load duct 12 through the inlet valve. Because of the flow a certain pressure difference arises over the piston 2 and when this pressure difference overcomes the spring force the valve 2, 20 closes before the inlet valve of the engine 30 and thereby gives EIVC - function.

In the extreme position A the throttle is completely open and the valve 2, 20 completely closed by influence of the movement of the arm 16 and the link 11. During this position 35 the valve is closed during the complete inlet stroke and thereby the EIVC- function is disconnected.

## CLAIMS

1. Device for reducing gas exchange losses or pumping losses of an internal combustion engine comprising a throttle (1) for controlling the pressure in the inlet manifold for the combustion air with or without fuel to the cylinders of the motor,

5 characterized therein,  
that in the inlet manifold (20) to every cylinder is provided a separate (1) throttle whereby the low pressure side of the inlet manifold relatively said throttle is supplied air or fuel - air mixture of higher pressure than the pressure of the low pressure side by a valve which at the start 10 of every inlet stroke is kept open and which closes before the inlet valve of the engine closes whereby the closing function of the valve is actuated by the position of said 15 throttle.

2. Device according to claim 1,

20 characterized therein,  
that said valve comprises a valve body, valve spring and valve seat whereby the valve body is arranged clamped by means of the valve spring against a settable stop (11;60) which is actuated by the position of the throttle so that 25 the valve body takes a certain distance from the valve seat at the beginning of the inlet stroke and obtains a closing function when the gas flow increases and gives a difference surface pressure on said valve body in inverse proportion to said distance set by means of said stop (11;60) between said 30 valve body and valve seat which difference surface pressure acts against the force caused by the valve spring.

3. Device according to claim 1 or 2,

35 characterized therein,  
that said valve is arranged on the throttle (1).

4. Device according to claim 1,  
characterized therein,  
that said valve is provided with an opening (10) towards the  
low pressure side of the manifold and air supply takes place  
5 by a partial load air duct (12).

5. Device according to claim 2 and 3,  
characterized therein,  
that said valve body is formed as a flap (210) which seals  
10 against an opening (230) in the throttle disc (100) whereby  
the flap is kept against the stop (60) by a prebending of a  
resilient portion (31) which stop determines the opening (z)  
of the valve flap (210).

15 6. Device according to claim 2 and 4,  
characterized therein,  
that said valve body is formed as a cylindric piston (2)  
open at one end, which piston is slidable in a house (22) on  
said partial load air duct, the open end of the cylinder  
20 seals in its end position against a valve seat on the inlet  
manifold (20) and receives a valve spring (21), which keeps  
the piston (2) against the link (11) which determines the  
stroke (z) of the piston (2).

25 7. Device according to claim 1 - 6,  
characterized therein,  
that the through flow area of said valve in the rest position  
is influenced by the throttle control by way of mechanical  
link systems (15,16;102,51) so that by choked throttle  
30 (position B) an increase of the throttle only increases the  
through flow area of said valve to a maximum ( $z_{max}$ ) and at  
further opening of the throttle gradually reduce the through  
flow area to closed valve at full throttle opening (position  
A).

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8. Device according to claim 1 - 7,  
characterized therein,  
that an injection nozzle (25) for fuel is placed downstream  
of the throttle (1).

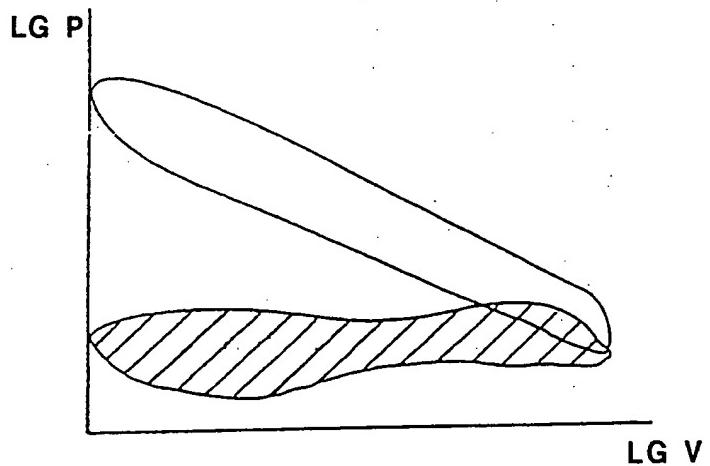
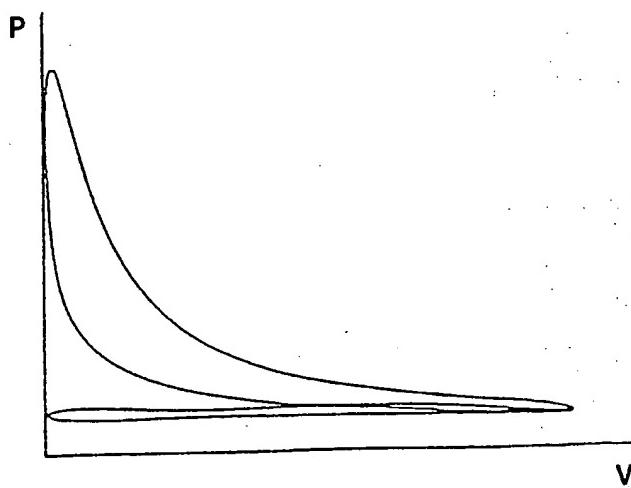
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9. Device according to claim 1 - 7,  
characterized therein,  
that an injection nozzle (25) for fuel is placed upstream  
of the throttle (1).

10

10. Device according to claim 6 - 9,  
characterized therein,  
that said partial load air duct (12) is fed by air from a  
compressor driven by an exhaust turbine.

1:7

**FIG. 1a****FIG. 1b****SUBSTITUTE SHEET**

2:7

FIG. 2

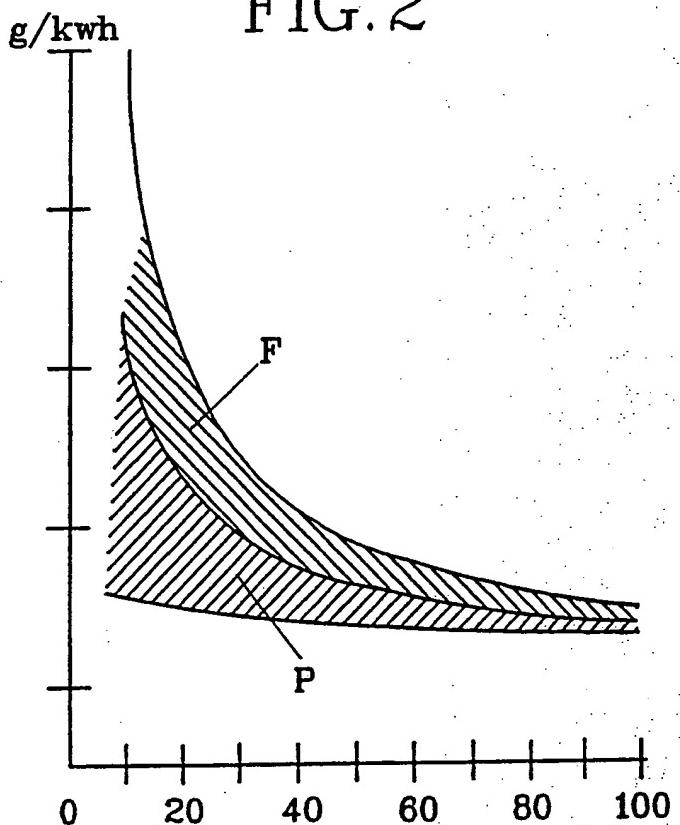
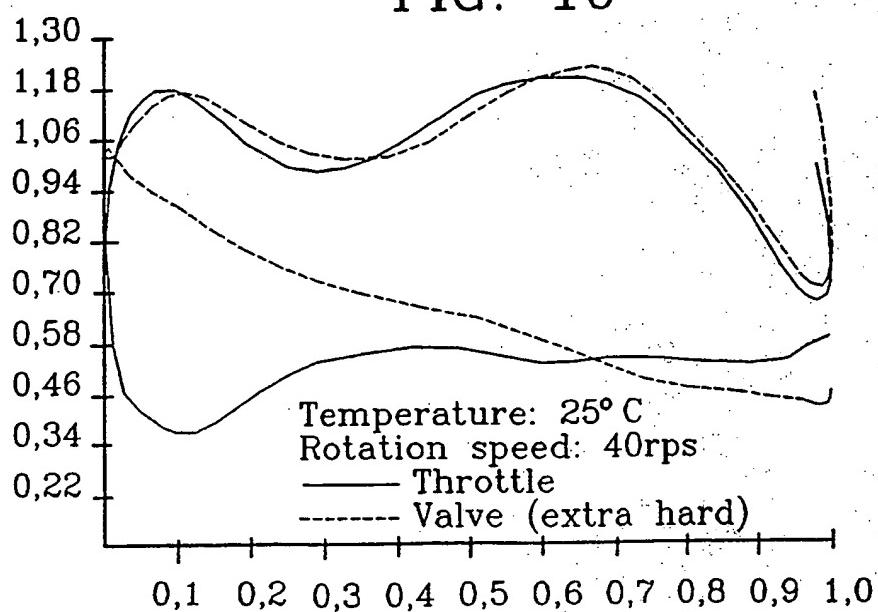
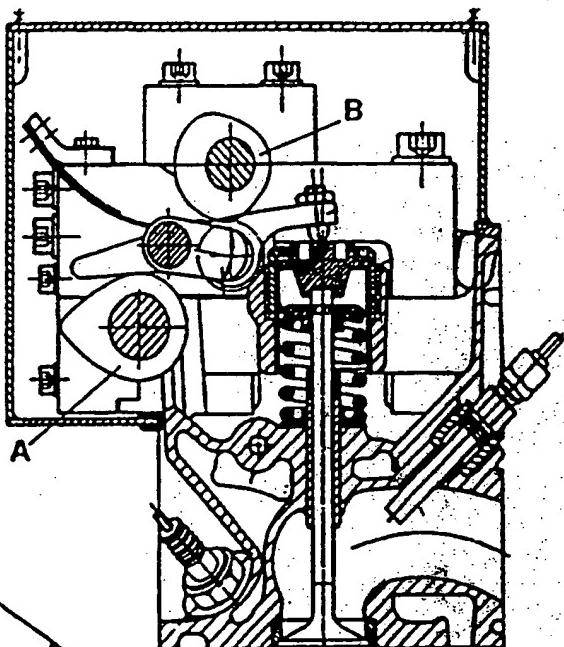
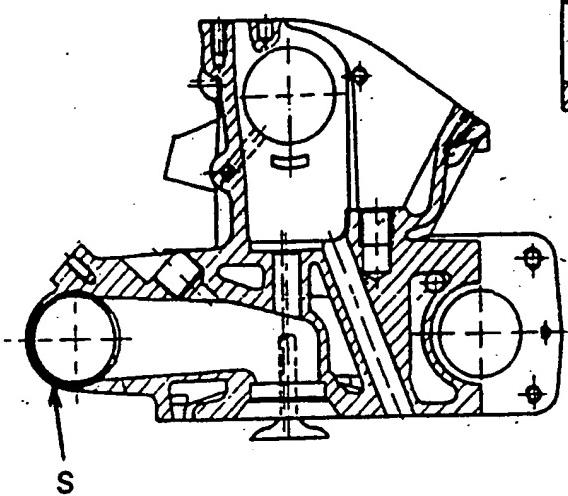
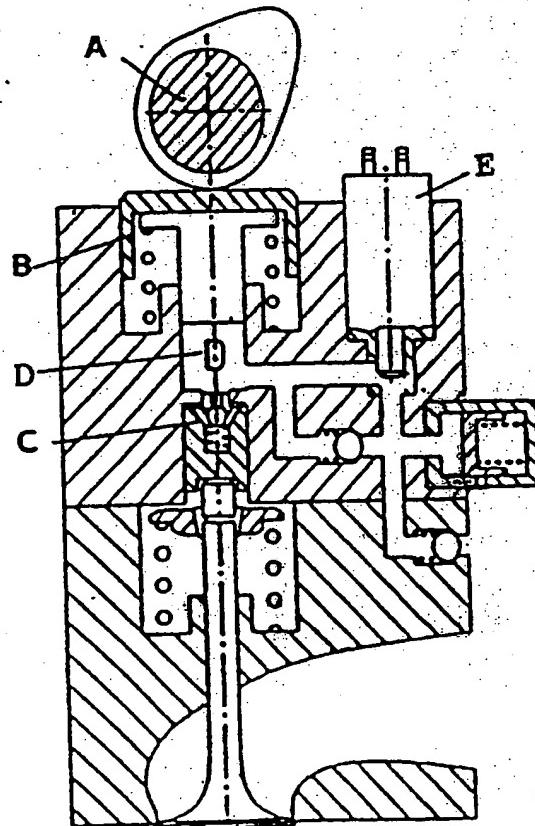


FIG. 10

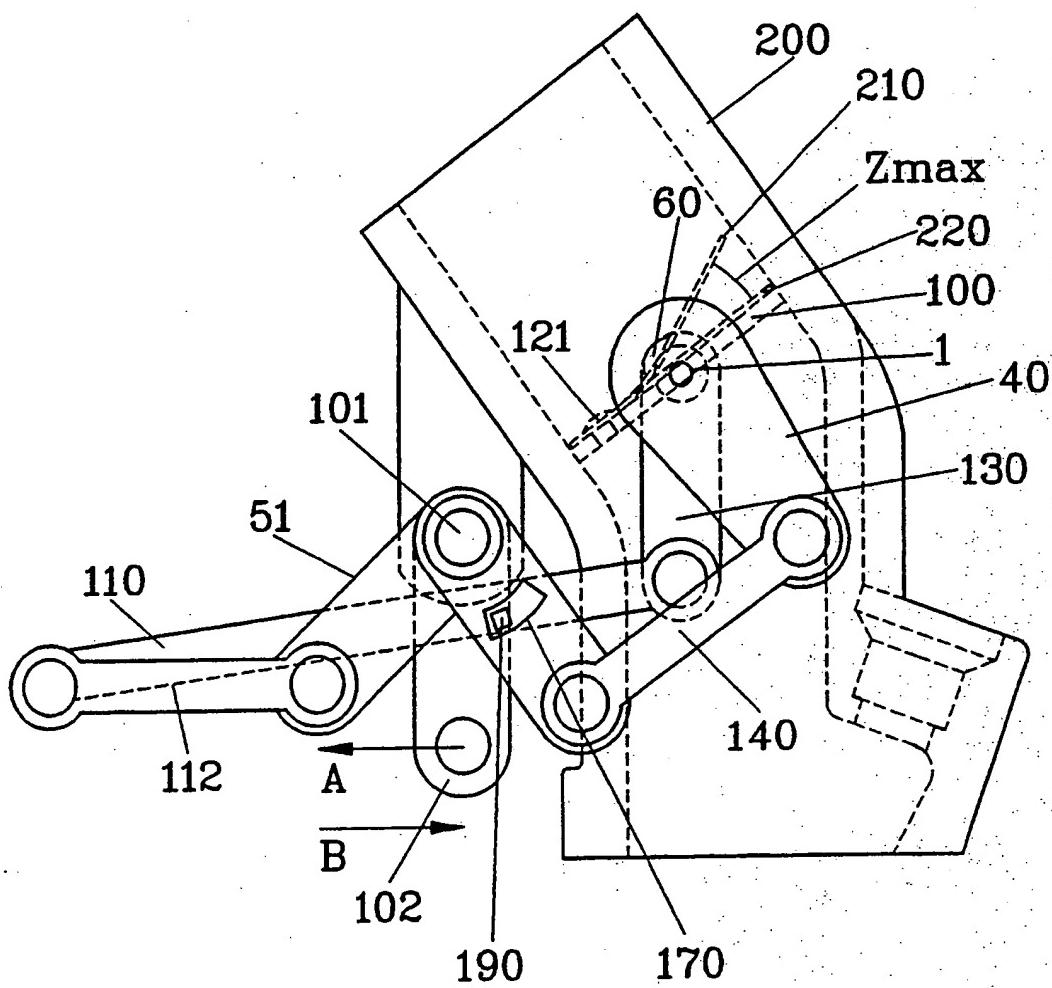


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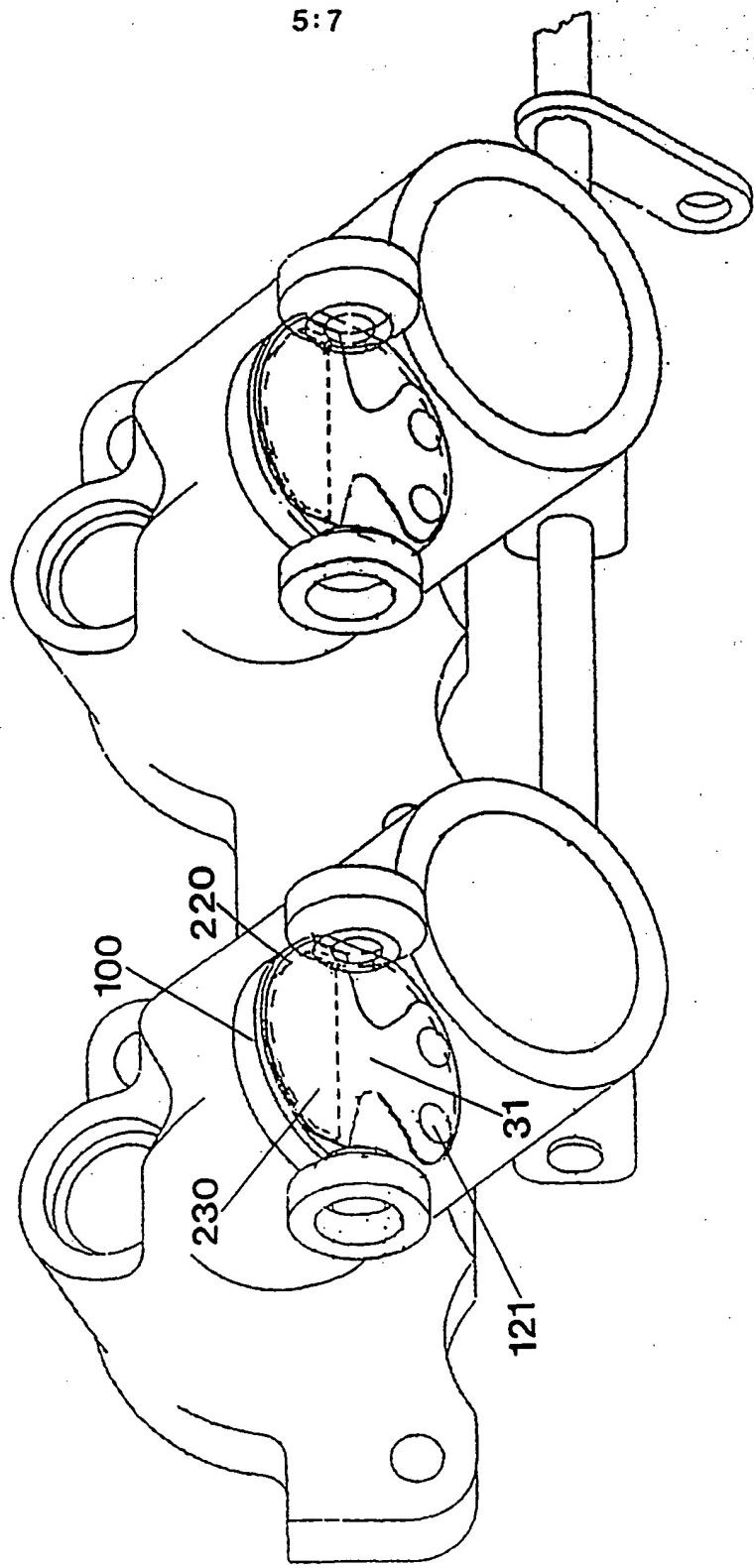
**FIG. 3****FIG. 4****FIG. 5****SUBSTITUTE SHEET**

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FIG. 6



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**FIG. 7**

6:7

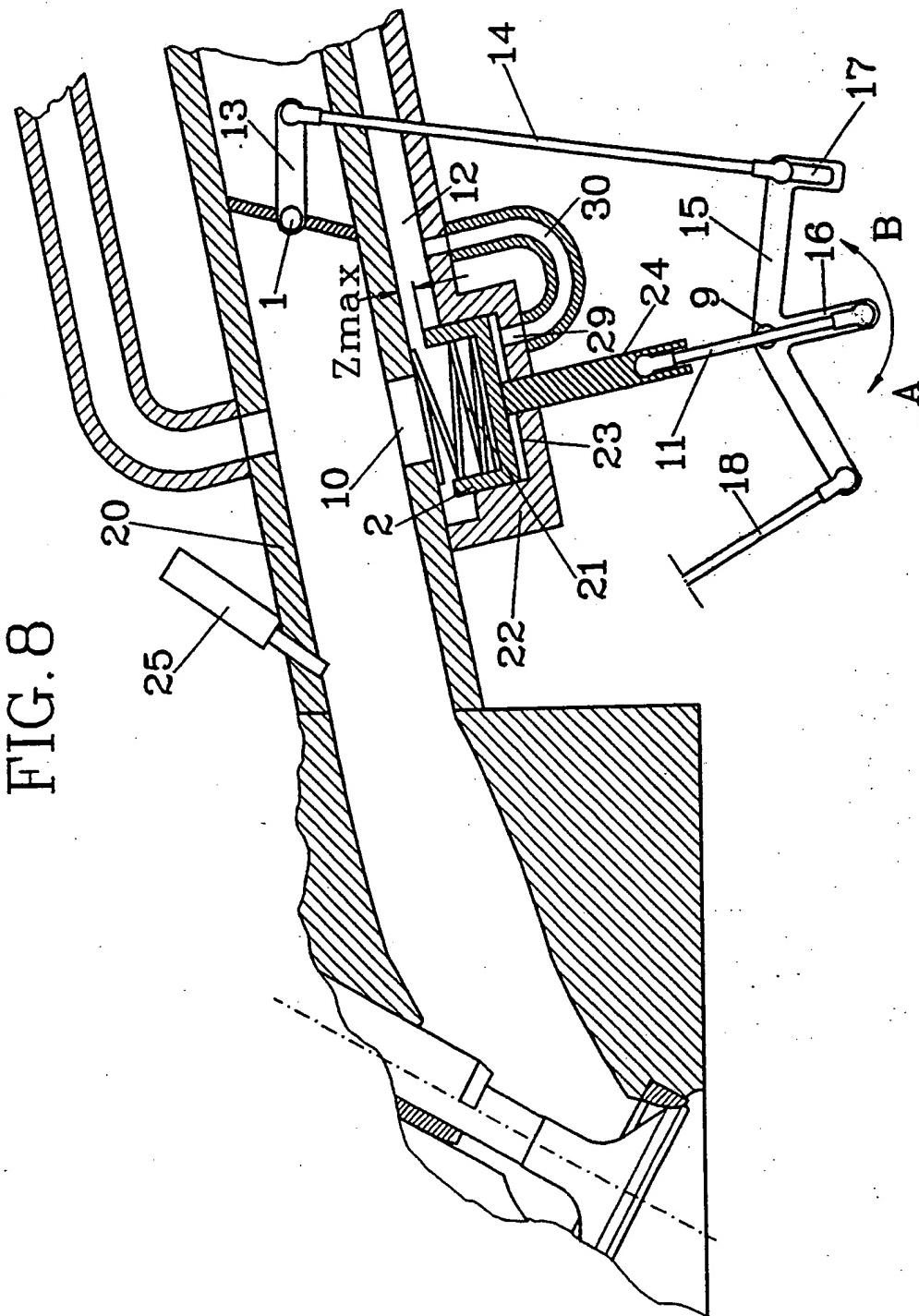
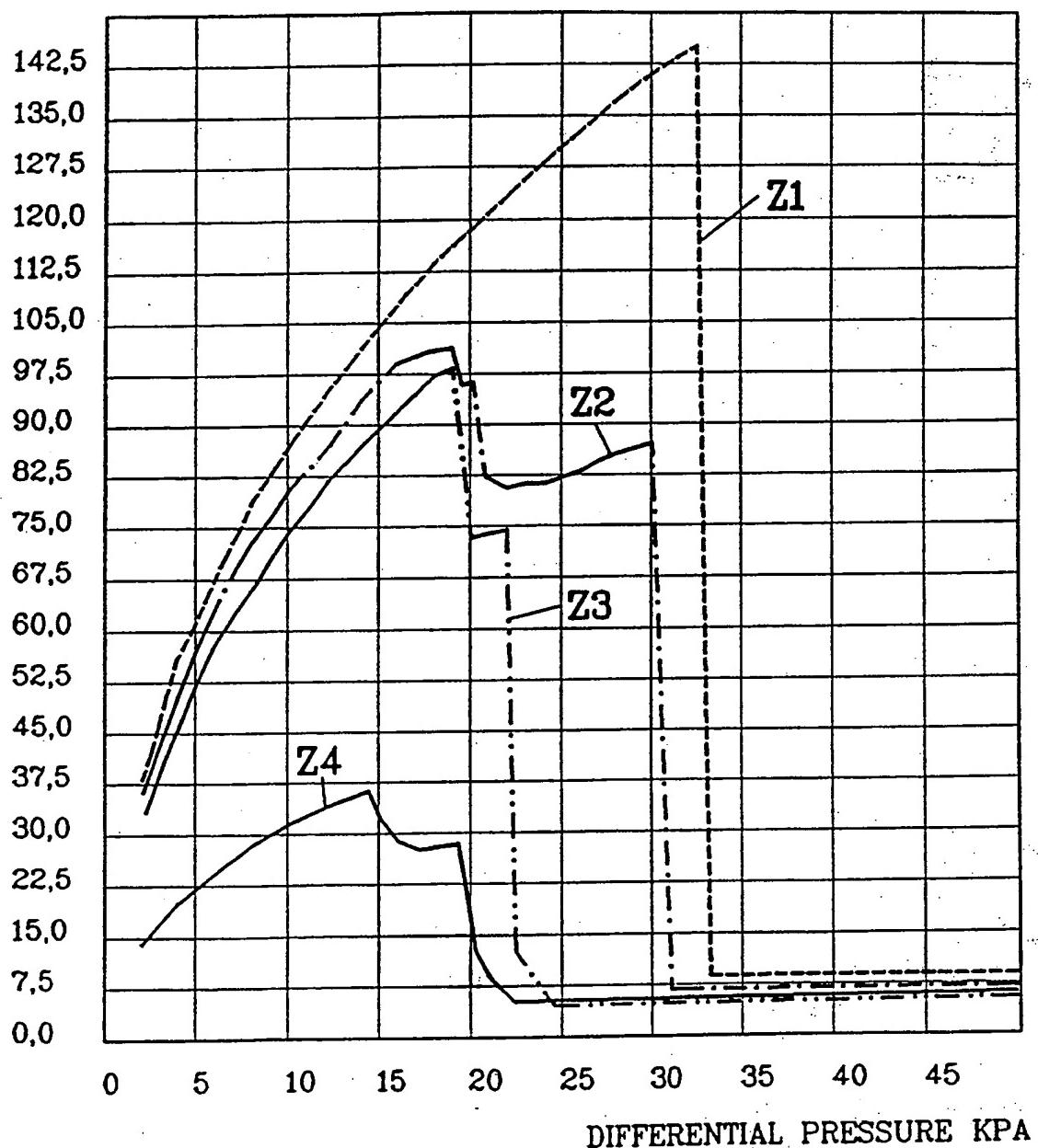


FIG. 8

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MASSFLOW kg/H

FIG. 9



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# INTERNATIONAL SEARCH REPORT

International Application No. PCT/SE 90/00634

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)<sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC  
**IPC5: F 02 D 9/02, F 02 M 35/10, F 02 B 27/00**

## II. FIELDS SEARCHED

Minimum Documentation Searched<sup>7</sup>

| Classification System   | Classification Symbols |
|---|------------------------|
| IPC5  | F 02 B; F 02 D; F 02 M |
| Documentation Searched other than Minimum Documentation<br>to the Extent that such Documents are Included In Fields Searched <sup>8</sup> |                        |

SE,DK,FI,NO classes as above

## III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup>

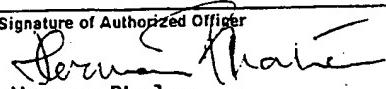
| Category <sup>10</sup> | Citation of Document <sup>11</sup> with Indication, where appropriate, of the relevant passages <sup>12</sup> | Relevant to Claim No. <sup>13</sup> |
|------------------------|---|-------------------------------------|
| A                      | US, A, 3935842 (ISHIZAWA ET AL) 3 February 1976,<br>see column 2, line 42 - column 3,<br>line 3<br>--         | 3,5,7                               |
| A                      | US, A, 4254747 (SUMIYOSHI ET AL)<br>10 March 1981, see column 4, line 3 -<br>line 30<br>--                    | 1,4,7                               |
| A                      | US, A, 4158352 (BLATTER) 19 June 1979,<br>see column 2, line 43 - column 3,<br>line 7<br>--<br>-----          | 1-3,5                               |

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- "&" document member of the same patent family

## IV. CERTIFICATION

| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report |
|---|---|
| 23rd November 1990  | 1990-12-21  |
| International Searching Authority                         | Signature of Authorized Officer                     |

  
Herman Phalen

SWEDISH PATENT OFFICE

ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.PCT/SE 90/00634

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
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| Patent document cited in search report | Publication date |  | Patent family member(s)   | Publication date   |
|--|------------------|--|---|--|
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| US-A- 4254747                          | 81-03-10         |  | JP-A- 54137515  | 79-10-25   |
| US-A- 4158352                          | 79-06-19         |  | AU-D- 3987078<br>CA-A- 1087943<br>DE-A- 2841082<br>FR-A- 2404745<br>GB-A- 2005770 | 80-03-20<br>80-10-21<br>79-04-12<br>79-04-27<br>79-04-25 |